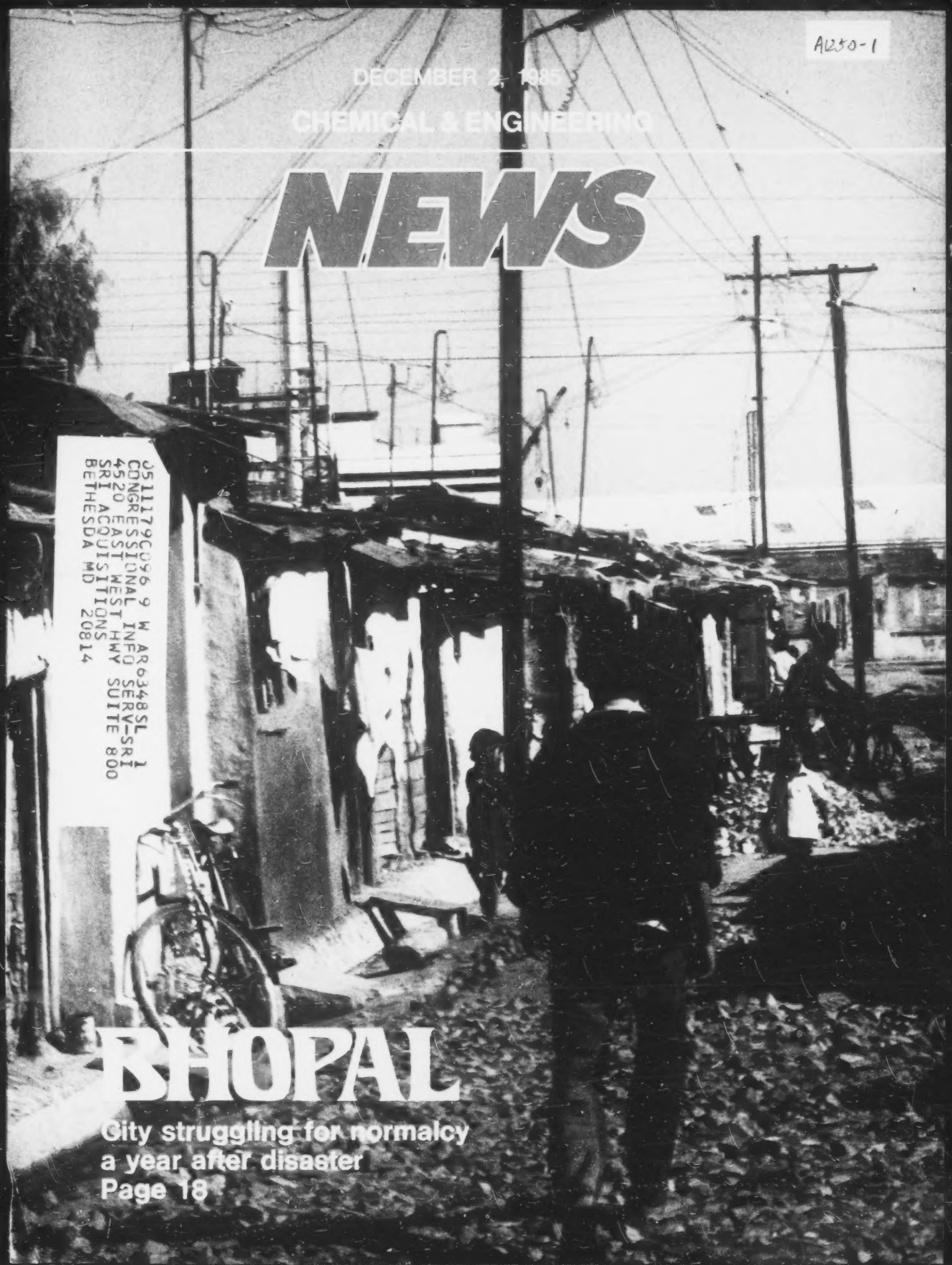
AR250-1

DECEMBER 2, 1985
CHEMICAL & ENGINEERING

NEWS

J5 111179C096 9 W AR0348SL 1
CONGRESSIONAL INFO SERV-SRI
4520 EAST WEST HWY SUITE 800
SRI ACQUISITIONS
BETHESDA MD 20814



BHOPAL

City struggling for normalcy a year after disaster
Page 18

CHEMICAL & ENGINEERING NEWS

Volume 63, Number 48
CENEAR 63 (48) 1–48
ISSN 0009-2347

DECEMBER 2, 1985

News of the Week

■ **Tax changes proposed by House Ways & Means Committee get cold shoulder from industry.** **Page 4**

■ **House committee chairman tells EPA to re-examine its air pollution inspection program after GAO finds it lacking.** **Page 5**

■ **Monsanto to sell oil and other energy interests to subsidiary of Australian firm.** **Page 5**

Business

Capital spending by majority-owned foreign subsidiaries of U.S. chemical companies is increasing, despite the leveling off of domestic spending; more and more is going to developing countries. **Page 7**

International Business

Japanese chemical companies improved sales and profits in first-half 1985, but the second half may be less profitable. **Page 8**

Government

New Jersey lawmakers score EPA strategy to clean up hazardous waste dump, saying method is untested, inadequate. **Page 10**

Technology

Study on research needs and opportunities of chemical engineering, prepared under sponsorship of the National Research Council, is optimistic about boosting U.S. industrial strength. **Page 14**

Cover: Photo by C&EN's Wil Lepkowski

Letters 2
Editor's Page 3

Concentrates
Business 6
Government 9
Science/Technology 13

The Departments
Meetings 47
Newscripts 48

Special Report

Bhopal—one year later—is showing signs of emerging from the disaster, but many conflicts, problems, and questions remain. **Page 18**

U.S. Chemical Spending Abroad To Rise

Chemical companies will be spending more for new plant and equipment in foreign countries next year.

U.S. companies seem to be on an overseas building binge. Although capital spending in the U.S. has remained fairly level because of lackluster capacity utilization and soft pricing, spending on new plant and equipment by majority-owned subsidiaries of U.S. chemical companies is moving up for the second year in a row.

The Department of Commerce estimates capital expenditures in 1986 by foreign subsidiaries of U.S. firms in chemicals and allied products will total about $3.37 billion, an increase of 14% from this year. Similarly, the 1985 estimate of $2.96 billion is up 13% from the 1984 spending level.

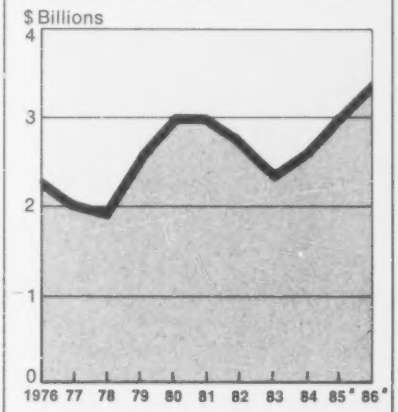
According to the government figures, the healthy increase for chemicals for 1986 is far and above that for all industries. Capital spending for foreign subsidiaries of all industries in 1986 is estimated to increase only 2%. This represents a considerable pullback from 1985, when estimates place capital spending for all industries almost 15% above 1984 levels.

The same pattern holds true for all manufacturing. Capital spending by overseas subsidiaries for this group was estimated up almost 16% in 1985 from the year before. Between 1985 and 1986, however, it is expected to increase just a little more than 1%.

On a historical basis, though, chemical foreign capital spending is still not exactly a bright spot. Since 1976, average annual growth of chemical capital spending abroad has been only about 4%. This happened in spite of the double-digit inflation in the late 1970s. Thus, in real terms, capital spending is probably near or below that of 10 years ago.

In the past 10 years, the chemicals and allied products subsidiaries have shifted capital spending subtly but significantly away from traditional, industrialized countries toward the developing nations. In 1976, 83% of capital spending went to developed countries, with the remaining 17% going to developing countries. In 1985, the developed countries' share had fallen to 80%, with 20% going to developing countries. And, in 1986, the shift will continue with 78% of the capital spending by foreign subsidiaries going to developed nations, and 22% to developing nations, according to Commerce Department estimates.

Spending by foreign subsidiaries up since 1983



a Estimate. **Source:** Department of Commerce

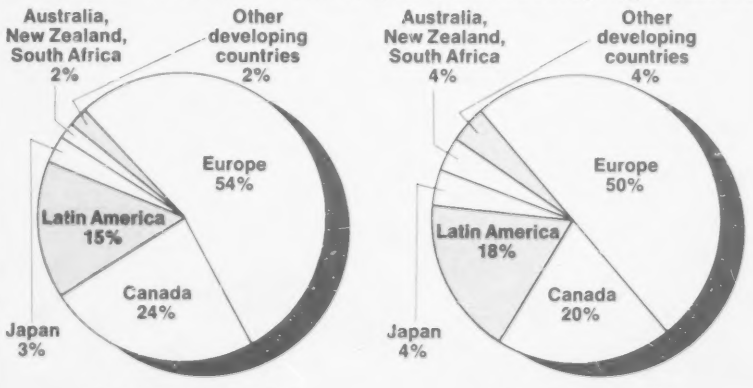
In 1986, chemical capital spending to the developed countries will rise 12%, whereas that to the developing nations will increase more than 20%. This follows an 11% increase to the developed countries and a 23% rise to the developing countries in 1985.

The European Economic Community is the largest market for capital spending by the chemicals and allied products foreign subsidiaries. In 1986, chemical capital spending in Europe will total $1.7 billion, or 50% of all capital spending by foreign subsidiaries of U.S. firms. This is up almost 16% from 1985 spending.

By far the largest slug of capital spending monies to any single country goes to Canada, the U.S.'s biggest trading partner. In 1986, Canada will receive $681 million, or 20% of all capital spending by chemicals and allied products subsidiaries. This is up 10% from 1985, when Canada received almost 21% of all chemical capital spending. Between 1984 and 1985, capital expenditures in EEC increased 5%, while capital spending to Canada climbed almost 22%.

In 1986, capital spending to Organization of Petroleum Exporting Countries will increase 20% to $49 million, after a 51% rise in 1985. □

Chemical investment shifting toward developing countries



a Estimate. **Source:** Department of Commerce

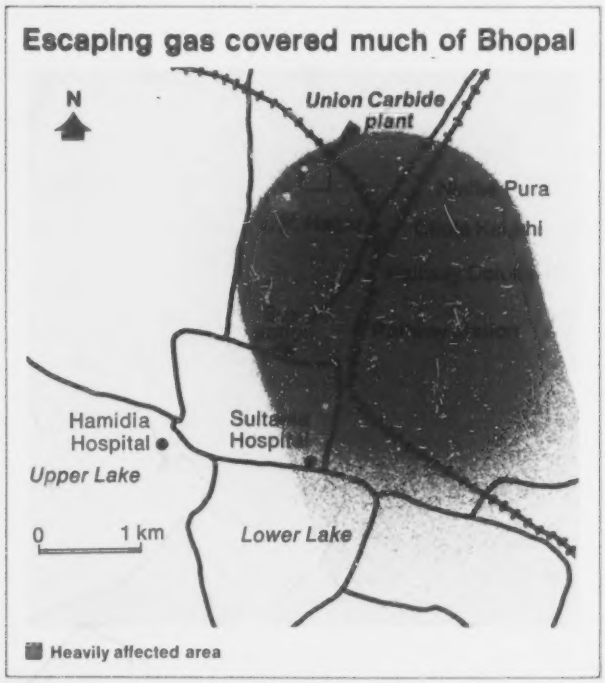
BHOPAL

Indian city begins to heal but conflicts remain

Wil Lepkowski, C&EN Washington

Bhopal one year later and the images stream back. The storage tank of methyl isocyanate (MIC)—41 metric tons of it—cooking within from reactions with contaminants. Molecules polymerizing, heat rising beyond 100, then 200 °C. The contents boiling to such frenzy that the tank's concrete casing shakes and cracks. Gases and liquids bursting through a rupture disk and relief valve, then surging through vent lines toward their final release through an overwhelmed scrubber.

Worker panic in the plant, a sleeping community outside as the gas begins to spread. Bodies roused, coughing, crying out, eyes burning and watering. Thousands running, staggering through the dusty streets and alleys, many clutching their babies, not knowing where to run to escape. Unconsciousness, injury, and death by the thousands. Pandemonium in the hospitals. By daybreak, the scene of silence around those left behind: fathers, mothers, children; cows, bulls, goats, dogs, all in final repose. A peace in its eeriness never more heart wrenching. The bodies disposed of by cremation and mass burials.



Then the local, national, and international responses. Medical supplies flown in. A planeload from the U.S. ordered back by Indian officials already thinking of compensation battles ahead. The sudden incarceration of Union Carbide officers who arrive to offer help. The dispute over the presence of cyanide in the gases. The invasion of U.S. lawyers. The overwhelming outpouring of local help. Schoolchildren, boy and girl scouts, bankers, merchants, the elderly—all transformed to paramedics and performing heroically. The visits by Prime Minister Rajiv Gandhi and Mother Theresa. The tense, circuslike atmosphere of Dec. 16—"Operation Faith" day—when the remaining MIC in an adjoining tank is converted to its final insecticide product, Sevin. The nine-month investigation by India's Central Bureau of Investigation. The now-suspended criminal investigation by a state commission.

Today, Bhopal is a hotbed of unrest, reform, and rebuilding as it struggles toward a future. Mass demonstrations and memorial events are scheduled this month in commemoration of the first anniversary of the disaster. A repentant Union Carbide India Ltd. has prepared a press kit outlining its program of various relief measures. The Poison Gas Struggle Front (known by the Hindi word "morcha"), an infuriating goad to the local establishment, is staging a mass march demanding that Carbide be punished and ejected from India. The government of Madhya Pradesh—the state of which Bhopal is the capital—has scheduled a symposium with an international cast

Photos by C&EN's Wil Lepkowski

An effigy of Carbide management (top) sits at plant gate; Bhopal family displays optimistic smiles

of writers and artists commissioned to deliver eulogies. Over the past year documentaries have been prepared, poems written, plays performed, paintings shown. Poster shows on the misuse of technology have been circulated to science classes in schools throughout the state. In New Delhi an international symposium is being held that will announce to a world kept in the dark thus far the results of Indian investigations of the tragedy's medical effects.

Memorials, too, are being planned. One will be a research center designed along the program lines of the center in Hiroshima, which for 40 years has been following the condition of the atomic bomb victims and their progeny. Another will be attached to a Madhya Pradesh Institute of Disaster Management, expected to be an international magnet for experts in that field. A Bhopal disaster museum connected to Bhopal's stylistic art center, Bharat Bhavan, is in the works. Plans are under way to make the Gandhi Medical College a top-grade research center with particular strength in industrial pathology.

On the surface Bhopal remains today as it was before the calamity: a buzz of open air markets, shops and human beings moving nonstop from dawn to hours past dusk. In one stricken area, signs of physical change stand out: a few television antennas on rooftops, new homes sturdier than the shacks they replaced, drainage canals in place, new paving on the pathways.

The city is no longer as stunned as it was a few months ago, though thousands are debilitated and unable to work. Mental illness as a result of the accident is one of the most serious health problems. The official government death toll is around 1800. Doctors are willing to concede that another 500 to 1000 could have died unaccounted for during the first 24 hours. Official state government figures say 320,000 persons out of Bhopal's total population of about 1 million were affected in some way, about 14,000 "seriously." About $2.3 million has been spent on cash payments to families who lost members in the tragedy.

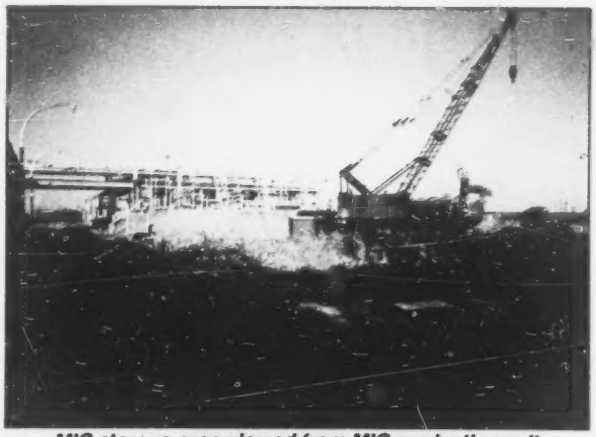
It is difficult, however, to measure what level of help the city needs. Officials tick off assistance figures—cash payments to families with fatalities, numbers treated for lung fibrosis, estimates of stillbirths, pounds of rice and wheat distributed, rupees handed out, the 20,000 x-rays and 35,000 clinical tests performed at Hamidia Hospital, the 1775 beds available now to gas victims.

But the numbers mean little against the magnitude of the disaster, still incomprehensible today. In any of the 30 urban wards, chats with people that were affected by the gas always reveal some unmet need. "These days, everyone is a gas victim," quips one government official. As Bhopal's current mayor Deepchand Yavad indicates, one may as well assume everyone in Bhopal was gassed. But that's a politician talking. Bhopal's pistonlike vitality makes one question claims of any urban malaise there.

Medical care, especially for lung, eye, and intestinal damage, is readily available. Every day hundreds line up at volunteer clinics, mobile treatment centers, or government outpatient facilities around the city. But an issue of high controversy is the extent to which affected persons are being actively sought. Local medical officials say that 34,000 persons have been visited by doctors inquiring about any problems. Records are being kept on everyone being treated. But to critics that isn't enough. Too many victims, they believe, are being ignored.

So there are stories in Bhopal today, and stories within stories—about the cause of the disaster, the dazzling pastiche of short- and long-term health effects, the relief measures, the controversy over the presence of cyanide in victims' bodies, the behavior of Carbide during the early hours of the disaster, the

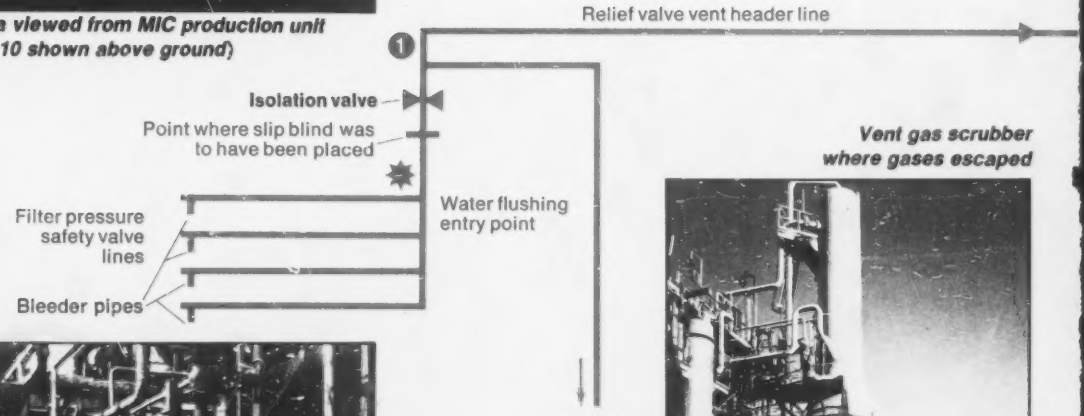
Four theories have been advanced on how water may have entered MIC storage tank

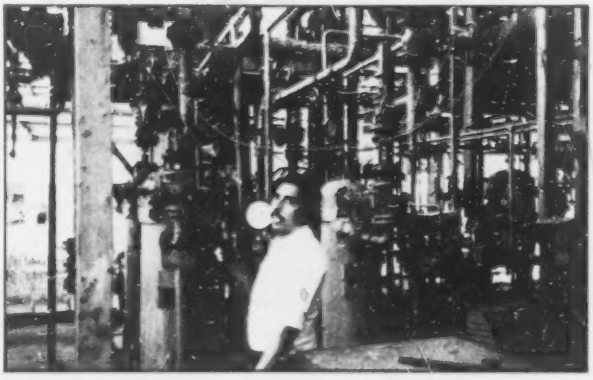


MIC storage area viewed from MIC production unit (tank 610 shown above ground)

1. A worker flushing out 2-inch pressure safety valve lines on the evening of Dec. 2 could have failed to insert a slip blind (a disk-shaped barrier) and thus allowed water to flow through a leaky, supposedly closed valve into an 8-inch line. The water moved through this line about 600 feet and then through a jumper line into the process vent line, which led directly to the storage tank

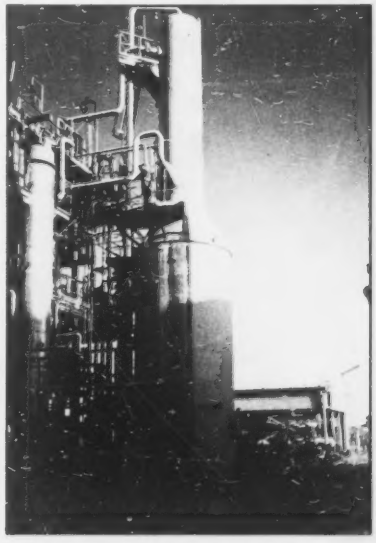
2. Water could have entered at some point in the nitrogen line near the tank





Area of pressure safety valve lines near MIC production unit

Vent gas scrubber where gases escaped



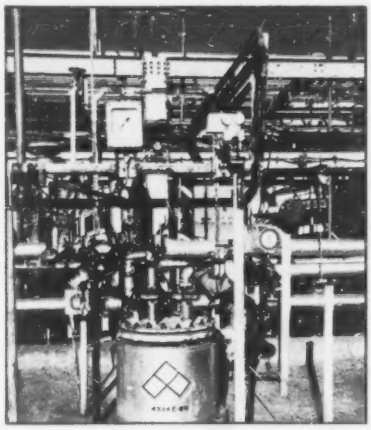
tangled legal story, the state of morality and legality in a culture as contradictory as India's.

The cause: its engineering, its implications

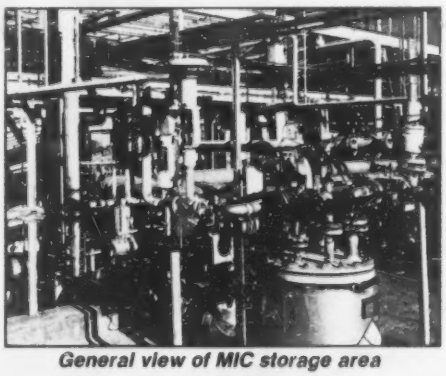
After a year, little is known for certain about what caused the runaway reaction in tank 610 at the Bhopal plant. What is well known, of course, is that the MIC stored in it underwent a hydrolysis reaction that, in turn, triggered a series of heat-generating polymerizations, additions, and degradations.

The resulting pressure burst the tank's rupture disk, blasted through the pressure valve just above it, and the gases surged about 600 feet along the 8-inch relief vent line, past various branch lines, and into the scrubber. They overwhelmed the scrubber's capacity (it was designed only to handle process vent gases, not runaway reactions from storage) and the gases escaped unneutralized.

The flare tower, also designed only for process vent products and moderate flows from the storage area,



MIC tank 611



General view of MIC storage area

was shut down for repair. Since the plant was not producing MIC or anything else that night, it made little sense to operating personnel to keep the flare burning. Moreover, a system of pressurized sprinklers that would have formed a "water curtain" over the escaping gases was itself deficient. Water pressure turned out to be too low to reach the height of the escaping gas.

Essentially three theories prevail to explain how it happened. One is sabotage (or mischief) by the insertion of water or contaminants into one of the lines leading into the tank. Carbide says its studies indicate that up to 240 gal of water could have entered this way. No other explanation but one of deliberate intent makes sense, the company says. The vast majority of Indians scorn the sabotage theory.

A second theory involves the "missing slip blind," whereby a worker, ordered to wash out a series of 2-inch pressure-safety valve lines near the MIC production unit, forgot to insert a disk meant to prevent

Browning (left): cupful of water
Bisarya (middle): long-term effects
Bhandari: they feel reassured

water from rising up into the main vent line, called the relief vent header. The water, the theory goes, flowed up the line toward the MIC storage area, passed into a jumper line connected to a process vent line that led directly into the tank. This is the theory that labor, environmental, and popular activists embrace because its source is workers who claim to know what happened.

The third theory is inadvertent contamination by combinations of rust, metallic ions, chloride ion, as little as a "cupful" of water, because of lax monitoring, sloppy maintenance, and inferior technology. Indian scientists doing their investigation tend toward this view and, believing it, are warning the U.S. that until Carbide itself fully understands what happened, it could happen again wherever MIC is stored.

As the UCIL production superintendent, S. P. Choudhary, told C&EN during a tour of the Bhopal plant last month, "We just didn't know that MIC could be that reactive." Choudhary, one of the UCIL management group facing criminal prosecution by the Madhya Pradesh government, rules out all theories that would account for process contamination of lines leading to tank 610. "We do not believe that a small amount of water would have caused this runaway chemical reaction," UCIL says in a statement.

Jackson B. Browning, the parent company's vice president for health, safety, and environmental affairs, adds that the small amount of heat generated by such a small input of water would have been absorbed by the bulk of the contents.

One particular sabotage theory, advanced by Carbide during Congressional hearings after the disaster, also has been ruled out by Choudhary. According to that scheme, the "saboteur" was supposed to have attached a water hose at the source of the nitrogen line that led to the tank and simply let the water run. That scenario has several holes. For one, the source of nitrogen was at least half a mile away from the tank, in an area owned by the company that supplied nitrogen to the Carbide plant. The pressure needed to reach the MIC tank, which itself was under positive pressure, however slight, would have been too great. More telling, though, is that investigations showed no trace of water in the nitrogen line after the accident.

The slip blind theory is also illogical, he says. The reason is that a valve a few inches up from where the slip blind was to have been placed was, records show, closed. Even if the valve leaked, he says, it is improbable that even small amounts of water would have risen about 12 feet to a line that widened to a diameter of 8 inches and then continued some 600 feet to a storage tank that not only was under pressure but, by that route, closed to entry of anything (both the pressure valve and rupture disk were closed tight).

But there was another way not mentioned by Choudhary, via that jumper line between the relief valve line and process vent line. This line, open or shut by valves—how many isn't clear—led directly to the tank. Everyone who has studied the accident agrees this could be a port of contaminant entry. Contaminants might have passed along the relief valve line, across the jumper line, into the process vent line, and into the tank. The scenario assumes a lot of valves that were not just leaky but open. A third option was the nitrogen line at the area of entry into the tank. A fourth involves lines that carried MIC out to a refrigeration unit and back into the tank.

So Choudhary says there is only one option left: "Someone deliberately did it. There are lots of places in any plant where with a simple tool you can detach a linkage and add a contaminant." And a source of water existed a few feet away from the tank. But one needs a motive. Carbide hasn't really supplied the motive, except for newspaper accounts of a radical Sikh group that claimed credit for the disaster. The problem is that the existence of such a group is yet to be verified nationally.

The view of Indian scientists involved in the government's investigation of the accident is that the answer lies in contamination from corrosion. They believe the accident was just that—an accident—but

that it was avoidable, and that the fault lay with the parent company, Union Carbide Corp.

"We have proof," says an Indian close to the investigation, "that the process know-how and design provided by Carbide were defective. Any other company in India purchasing foreign technology would have raised questions of why large quantities of stored MIC were necessary. UCIL could have asked something like that. But in this case, here is a plant owned by Carbide. The detailed design was Carbide's. Approval and acceptance of the mechanics and processing were done by Carbide before commissioning."

He goes on to itemize where the Bhopal plant design was deficient. "At the Institute plant, for example, there is an intermediate storage tank between the production and storage units. This is used for continuous sampling of the product. Second, the MIC storage tank in Bhopal was not equipped with safety instrumentation. Sound alarms and flashing lights go off if the pressure and temperature increase at Institute. There was no such warning system at the storage tank area in Bhopal. In addition, the chilling system was underdesigned. At the Institute plant, the storage tank itself has refrigeration coils. The Freon is circulated inside the tank. At Bhopal, the material was taken out and then returned. So the UCIL refrigeration system was underdesigned; the cooled MIC went right back into the tank, which was probably at ambient temperature most of the time. So it probably was never being chilled, even when the unit was on. I don't think the tank could have been cooled much below 15 °C."

Indian government laboratories are attempting to simulate the reactions that might have taken place, based on their own samplings of residues as their own check on Carbide's investigation. "We have taken samples of the tank's wall," says one source. "It's almost impossible to go in the tank now because it still contains highly lachrymating mixtures—trimers, dimers, isocyanates, dimethylurea, biuret."

S. Varadarajan, India's top scientist as director-general of the Indian Council of Scientific & Industrial Research, says he is worried about the safety of those working or living in the vicinity of MIC in the U.S. today. "I think that until the exact cause of the runaway reaction at Bhopal is explained," he says, "there should be a ban on shipments."

The medical results

One year after the disaster, Bhopal is one vast experimental ground of industrial toxicology. Every patient is in some sense a toxicological celebrity.

Figures on the total number who died are becoming less controversial by the month. Some activists are still holding out for a figure of up to 10,000, but their voices have quieted. Their claim has been that thousands of bodies were dumped by Army trucks anonymously in mass graves at sites some distance from the city. But no one has located any such graves and few families have come forward to register family losses beyond those reported months ago. So the term "more than 2000" is the best anyone can say. As it is, about 15 gas-exposed persons currently die every month in Bhopal, according to official state estimates. The figure is over and above the 250 or so normal monthly deaths in the colonies that were affected.

Women patients in Hamidia Hospital MIC ward

Medical studies are showing a bewildering array of physical and psychological problems among the affected. Children under 10, when asked to make drawings, inevitably put their crayons to crude depictions of Carbide, gas, and death. Strange sores, susceptibility to tuberculosis, persistently lowered oxygen transport are some of the complications rendered by exposure to the gases.

Some patients are classic cases, such as Dropdi Bai, a 55-year-old woman who has been hospitalized with pulmonary problems ever since the first night. Bai is special, because she is one of the few gas victims of Bhopal who has been under surveillance ever since the leak. She is likely to remain in the MIC ward of Hamidia Hospital for a long time. K. S. Gaur, the physician who administers the ward, says her major

Dropdi Bai: hospitalized since night of accident

pathology is bronchiotitis obliterans—blockage of her lungs' air passages. She is being given cortisone to reduce inflammations. She arrived at the hospital in a coma and showed signs of cyanosis. Sodium thiosulfate, the standard antidote to cyanide exposure, was tried twice on her, Gaur says, but with no relief.

Most of the research and treatment in the ward, he says, involves the effect of MIC on the lungs and on lung function. Other studies include the psychiatric aspects, gastrointestinal complications (varied and common), and the long-term complications of drugs such as cortisone, sodium thiosulfate, and Levamisol. "Many symptoms," he says, "can be explained by immunological disturbances."

The Indian agency in charge of continuing biomedical research on the Bhopal tragedy is the Indian Council on Medical Research, headed by V. Ramalingaswami. Located in New Delhi, ICMR has spent $2 million in research so far involving about 150 researchers. And gradually Ramalingaswami hopes most of the followup research and continuous monitoring will be done in Bhopal itself.

The most serious overt problems researchers are investigating involve the lungs, he says. "Whereas eye effects appear to be abating, lung problems are persisting. We're looking at the nature of the disturbances induced by MIC. For those who received moderate to high exposure of the gas, lung edema developed rapidly, and scarring of the alveoli is common. These changes also have made the patients susceptible to pneumonia.

"Extensive studies have shown," Ramalingaswami adds, "that patients have an obstructed as well as restrictive element." That is, they not only absorb less oxygen but breathe in less as well. The restrictive aspect could be due to muscle spasms that constrict and narrow the lumen.

"Lung damage is the most serious and most important of our efforts," he says. Bronchodilator drugs are the most common treatment, but if the causes of the lung problems are getting increasingly subtle, other forms of therapy may be needed, he says. Breathing therapy, for example, is just being started. And it turns out that instruction in yoga breathing techniques is the form of physiotherapy chosen. Researchers are saying there is no known technique more effective for expanding lung capacity.

The immunological aspect also could be involved in explaining some of the more subtle, restrictive aspects of the lung damage, he adds. One study involving Indian scientists and Meryl Karol, an immunotoxicologist from the University of Pittsburgh, turned up detection of circulating antibodies after animal exposure to MIC—now called the MIC-specific IGE antibody. "If one detects it in the patients, the finding could lead us to believe the obstructive element could be the consequence of this immunological change."

About 3000 pregnant women were exposed to the gases, according to Ramalingaswami, and miscarriages and stillbirths were frequent. In the first 20 weeks, 436 spontaneous abortions occurred out of 2600 pregnancies. The normal rate in Bhopal is 6 to 10%. "Malformations are still being studied, although doctors are not noticing any increase of obvious birth defects," he says. "The genetic and cancer aspects of the gasing are the biggest unkowns and will have to be followed for years."

Heart surgeon R. K. Bisarya, the Bhopal mayor at the time of the tragedy and now back in full-time medical practice, takes a dour view of the medical situation in the city.

"Long-term effects are showing up now," he says. "And they are much worse than I expected. I am happy about the condition of eyes, however. I thought we'd have thousands of people needing corneal transplants. I'm glad to see that few do. But the long-range effects are bad. People's vitality is continuing to decline. Many feel they are not going to survive. There is lots of colitis, diarrhea, ulcers. A lot of female disorders. Lots of women delivered prematurely, though the fetuses were usually normal."

Bisarya thinks the state medical establishment made a serious mistake by not taking systematic records of the affected people from the very beginning. The focus was too much on treatment and not enough on the careful recording of symptoms.

"Also, I would have expected more involvement from American scientists and physicians," he adds. "Several people I know from Los Angeles said they were willing to come and spend a year or two. They needed government grants to do that. But the U.S. provided no such help.

"Legally, it would have been beneficial to have American scientists. If the case goes to court and our Indian scientists make a claim, Carbide will send in American scientists to rebut them. If we had Ameri-

Results of research on Bhopal victims by India's industrial toxicology center

Total studied:
- 508 males, 601 females

Age groups:
- 50%—10 to 35 years
- 17%—36 to 45 years
- 16%—under 15 years
- 9%—46 to 55 years
- 8%—over 56 years

Average monthly income:
- 300 rupees ($25)

Distance from factory:
- 61% less than 2 km
- 31% 2 to 4 km

Chest x-rays performed:
- 903, of which 739 were normal, 164 abnormal
- 91 suggested definite pathology
- 48 showed changes attributed to MIC

Biochemical studies:
- Glutathione level reduced in 30%, indicating hampering of detoxification mechanism and impairment of redox potential of biological system

Immunological studies:
- 55% showed lower phagocytic ability

Chromosomal studies:
- 31% showed chromosomal aberrations

Lung function tests:
- 39% showed ventilatory impairment

Behavioral/psychological studies:
- Difficulty in concentration was most common complaint. Also confusion, poor memory, headache, irritability, depression

Worker groups in India push for industrial, community safety

India is a nest of public interest groups. The Bhopal disaster has helped galvanize them, but they are by no means a new phenomenon. Their origins go back to Mohandas Gandhi and his opposition to the caste system and capital-intensive technology.

When India gained independence, young technical professionals believed they could achieve the Gandhian ideals for India through government service. But finding themselves frustrated by the red tape and petty politics of government many gave up on that hope and began organizing science/public interest groups in various states.

The major problem of these groups is that they are frequently attacked by India's merchant class as Marxist. They deny the charges but often counter that Marxist critiques of capitalist economics and politics are often on the mark and should be used as intellectual tools. In fact, they believe capitalism should welcome such sources of stimulation.

The Delhi Science Forum in New Delhi is one such group. Various scientific educational groups that teach science to children in the villages is another manifestation. Another, of course, is the radical Poison Gas Struggle Front in Bhopal. The government has a difficult time dealing with these groups, whose staff members are better educated than the average government professional.

The reason is that, on the one hand, these groups fulfill the Gandhian ideal of pure democracy in the form of free flow of information, which no one can really argue with. On the other hand, they force disclosure of public information the massive Indian bureaucracy routinely prefers to conceal. What they constantly suspect is a large system of bribery and payoffs between industrial and government officials.

Staff members of Society for Participatory Research in Asia

One group that has been particularly successful in maintaining its public interest integrity while creating effective bridges to government is the Society for Participatory Research in Asia (SPRA), located on the outskirts of New Delhi. It claims no leader but says it is run—Gandhilike—by a coalition of staff members.

SPRA defines itself this way: "Participatory research is a methodology based on the belief that knowledge is power, and therefore can contribute towards the empowerment of the poor. It promotes the involvement of the poor and oppressed, their organizations and representatives, in the creation and utilization of knowledge in their own collective interests. It thus attempts to challenge the monopoly over knowledge and its tools in the hands of the few."

Since Bhopal, SPRA is giving a lot of effort to reforming industrial safety laws, regulations, and practices in India and pressuring the trade unions to be more active on behalf of workers. "We're trying to work with social action groups and workers all over the country to inform people in rural and urban areas, slum dwellers, and workers so that they know their situation better," states Anil Chaudhary, a group spokesman. The activity takes the form of meetings, workshops, and a publication program. SPRA does no demonstrating, but does rest its sentiments with the average person. It was part of a team of public interest Indians that toured the U.S. last March on behalf of Bhopal workers who lost their jobs when Carbide shut down there.

The organization has published two major manuals since Bhopal. One is called, "Labor Movements and Legislations in India," a comprehensive history of worker protection in India. The other is "Occupational Health and Safety—A Manual for Activists," an impressively detailed fact book on such topics as noise, heat, chemical hazards, export of health hazards, plant hazards checklist, and occupational hazards and childbirth. Another publication is a model occupational and community safety act that India's Parliament is considering.

"No educational programs for workers or right to know laws exist in any industrial sector in India today," says Chaudhary. "We want to remedy that."

can scientists studying the medical problem we'd have a stronger case."

The Madhya Pradesh health services director M. N. Nagoo remains bitter toward UCIL for its behavior during the first hours. "UCIL never had any direct dialogue with us," he says. "Anything it wanted to do could have been done through the government. [The firm] never bothered about alleviating the conditions of the patients. I was continuously in the hospital for weeks and got no inquiries from UCIL. The night of the leak it never informed us of what to do. I got the alert from the chief commissioner. At 4 AM [company officials] were saying it was nothing more than eye irritation. At 2:15 AM—I still remember the time—people were saying something nontoxic leaked. They could have informed me, but they never did."

This is a subject of special sensitivity to V. P. Gokhale, managing director of UCIL. "We did not have enough knowledge about the acute, long-term effects of MIC at the time." He says the company sent telex messages to Carbide the day after the tragedy seeking answers, and that Carbide sent eye and lung specialists within a couple of days. He points out that the plant dispensary was treating 6000 victims. "On Dec. 3 we flew in our physician and brought along with us medicines, oxygen, respirators, and 120,000 rupees ($10,000)," he

A Bhopal portfolio

Grim reminders of Bhopal disaster are Carbide's plant (above), ashes of cremated victims (far right), and children exposed to gas, photographed shortly after tragic gas leak from plant

says. "At that time there was a lot of pressure on the medical community. Whatever supplies we gave were not acknowledged in writing. Then came the controversy over cyanide. That led some people to believe that UCIL deliberately misled the medical community. I don't know what our doctors were telling people. But the accusation that UCIL withheld information on long-term effects does not make sense. The truth is that we were unable to communicate to them what they needed to know."

Volunteer health organizations are upset with the government because they feel Madhya Pradesh physicians continue to underplay the extent of damage to women. Rani Bang, a Bombay-based gynecologist, reported in March that of 55 studies of women, 94% developed gynecological diseases like leucorrhea, 79% pelvic inflammatory diseases, and 46% menstrual bleeding. "Lactation suppression, impotence in husbands, stillbirths, and abortions have been other effects," her report stated.

Says Anil Sadgopal, leader of the Bhopal Poison Gas Struggle Front: "We were unwilling from the very beginning to accept the ways government doctors were downplaying the extent of problems. On Dec. 27 Ishwar Dass, then health secretary, was declaring that only eyes and lungs were affected. The rest of the systems he said were normal. To us activists in the field, working with the injured, the statement was shocking. Our survey teams had established that almost every organ of the body was showing one or another affliction. Gynecological disorders in various forms were observed by our doctors. And they are still showing it now."

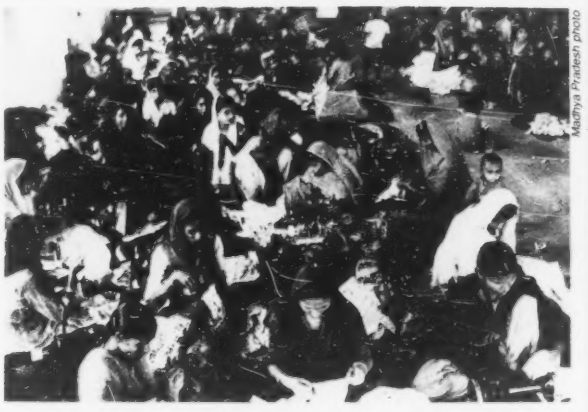
But although medical disputes continue, especially over cyanide toxicity, much of that strident period is past. N. R. Bhandari, superintendent of Hamidia Hospital, says women need reassurance as much as anything. He believes that publicity has been so intense around dangers to newborns that anxiety is common among pregnant women. Ultrasonic fetal monitors have helped calm some women. "When they see their living baby on the screen, they feel reassured," he says.

The relief efforts

Much of the agitation that has roiled Bhopal over the past year—riots, police beatings, storming of the state government's offices, a takeover by the morcha of the Carbide factory grounds—was in response to the slowness with which the Madhya Pradesh government was responding to the needs of the victims and to Carbide's unemployed workers. A superficial look at the gas-affected area, however, leads a visitor to conclude that significant changes are taking place.

Uniformed children sit attentively in one-room shacks that serve as schools. Little assistance centers dot the colony, one providing counseling services for women, another dispensing high-protein bread. Small shops are opening with money either given by the government or loaned to the villagers by, yes, UCIL.

Madhya Pradesh photo



Madhya Pradesh photo

In the accident's aftermath, Madhya Pradesh chief minister Vora visited gas-affected colonies (bottom left), new hospital began rising near Carbide plant (left), and center was established to teach sewing skills to women from gas-affected colonies

Some new homes, built solidly of stone, are seen, contrasting sharply with the crude tin and burlap shacks that still predominate. In one sense, the gas-affected people are the new elite of Bhopal. Some of those who never had it so bad now have never had it so good and are the object of envy by the rest of Bhopal's poor.

Down Berasia Road, which divides the colony from the UCIL plant, the government has opened cottage industry training centers. In one, more than 100 women, many widowed, work at sewing machines, turning out garments that the state will distribute in the remote villages of Madhya Pradesh. A knitting operation was opened in October. Last month a hosiery production unit got started. Men are being trained in new work, including television repair.

Dass, the Madhya Pradesh first secretary in charge of all relief operations, says the government has plans to build an export-oriented business that will produce fine products for the international market. Dass is a Ph.D.-holding organic chemist who long since has abandoned the lab for government service.

A person like him was needed, for through May, the situation was getting wildly out of hand in Bhopal. A drought was threatening the area's economy. Its chief minister, Arjun Singh, had left suddenly to take up duties as governor of Punjab. Because of the lack of leadership, relief measures were in chaos. Medical treatment and record keeping was a mess. The gas-affected people, led by the morcha, were demanding more medical, nutritional, financial, and community help. And the UCIL workers were getting restive by prospects of no work. May and June were marked by demonstrations and jailings of morcha and labor leaders, as the cyanide controversy began bursting into the headlines.

By May, the central government began intervening. The chief finance minister, V. P. Singh, the most powerful general policy figure in the Gandhi government, visited Bhopal and promised to break the financial logjam. At the same time, the state's new chief minister, Motalil Vora, began paying surprise visits to the affected colonies, meeting with people to hear their grievances.

Says Dass: "The morcha was dissatisfied with the way the scientific bureaucracy failed to convey information on anything important to the people. A motley crowd led by leftists came together and took a confrontational position.

"June 25 was the watershed. Since then they haven't been able to consolidate. When I took charge, I felt that once the people see what we are trying to do, the agitational scene will lose its relevance. Such organizations do have a role to play. I told the demonstrators to try to take over the wards and take up some concrete activities like comprehensive care."

Carbide is attempting to inject a permanent presence in Bhopal's rehabilitation efforts, and Dass says its efforts are always welcome. It is funneling some money in by anonymous means and has established a

trust fund of about $200,000, made up of contributions from Carbide's Indian and U.S. employees, to be used as a source of loans to survivors who want to start businesses. Clinics funded by UCIL are in operation. A leather products business has been started, funded by UCIL. The most ambitious project is a housing project that is currently going up.

The future of the plant site is still being determined. Carbide offered to make batteries there, or reopen the pesticide formulation plant. But the government would have none of that. Carbide has a 99-year lease on the site for industrial operations at a yearly rental of $600 a year. It has no intention of giving up the land and probably will appeal any order to depart.

"We have all our buildings and plant on the site," says UCIL's Gokhale. "There is a sizable investment there." The future of the pesticide research lab on a hill overlooking Bhopal is also unclear. Morale is poor there. Several researchers have departed. The government has suspended its tax-exempt status. It could be nationalized, or closed.

Not everyone is satisfied with the relief schemes in Bhopal. Sadgopal's morcha continues to agitate for more input for the affected people. The Rashtriya Abhiyan Samiti, another of at least a dozen public interest groups that have settled in Bhopal since the disaster, is one of Dass' sharpest critics. The group calls Dass' rehabilitation scheme a "cruel joke" on the victims.

"Only the government and its experts can explain how an aerodrome, a railway station, a botanical garden, a boating facility, and a swimming pool are related to the rehabilitation of gas victims," it says in a statement. "The government has proposed an expenditure of [$85 million] on such irrelevant schemes. There has been no attempt to satisfy the needs of the 80% worker population of the gas-affected areas employed as railway coolies, day laborers, bidi (cigarette) makers, tailors, petty businessmen, textile and paper mill workers, railway gangmen and peons, whose health, housing, and employment have been seriously affected."

J. P. Nagar is the showcase of the affected communities. But at other areas such as Kazi Camp and Railway Colony, off the official Bhopal gas tour, the pace of recovery seems slower, though government clinics and those run by various voluntary groups keep open house in all the colonies. At the Railway Colony, stories tell of residents there being forced to pay for their own treatment and care, including trips to Bombay for special care.

The relief story in Bhopal will be a source of continuing controversy for perhaps years.

Thiosulfate/cyanide issue is most controversial

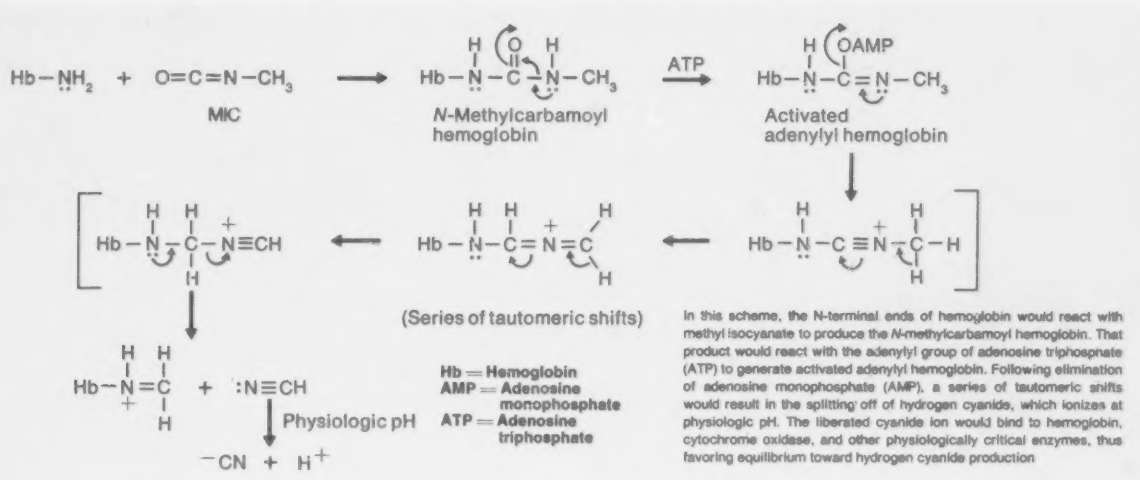
The issue over whether many of the Bhopal victims were and still are exposed to some form of cyanide poisoning is the most controversial aspect of the tragedy, and the most politically explosive. Indeed, as one Gandhi Medical College physician observes, "The cyanide issue is more sociopolitical than scientific." In the beginning, Madhya Pradesh medical officials and Carbide physicians denied any possibility of cyanide exposure among the gas-affected victims. Yet, on Dec. 6, three days after the event, scientists of India's Air Pollution Control Board were detecting cyanide at the MIC storage tank area and 50 meters downwind. At about the same time, doctors at Bhopal's hospitals were treating victims for cyanide exposure. (The presence of cyanide at the tank site is an intriguing notion, since the leakage was almost exclusively reported to be at the scrubber.)

By February, the Indian Council of Medical Research finished its study of cyanide exposure and in a March report recommended continued sodium thiosulfate treatment. It said that, although there was no longer any direct exposure to cyanide, reactions in-

Photo by Nagabhushan Rao

Dass (left): a deliberate act
Varadarajan (middle): people in U.S.
Gokhale: not enough knowledge

Proposed mechanism for generation of cyanide in the body after exposure to MIC



In this scheme, the N-terminal ends of hemoglobin would react with methyl isocyanate to produce the *N*-methylcarbamoyl hemoglobin. That product would react with the adenylyl group of adenosine triphosphate (ATP) to generate activated adenylyl hemoglobin. Following elimination of adenosine monophosphate (AMP), a series of tautomeric shifts would result in the splitting off of hydrogen cyanide, which ionizes at physiologic pH. The liberated cyanide ion would bind to hemoglobin, cytochrome oxidase, and other physiologically critical enzymes, thus favoring equilibrium toward hydrogen cyanide production

Source: Harold Teague, Pembroke State University

volving the body's "cyanogen pool" and biochemical by-products of MIC could be accounting for the success of sodium thiosulfate treatment.

The report pointed to improved condition of treated patients and increased urinary concentrations of sodium thiocyanate after treatment, indicating the presence of cyanide in the system. Since sodium thiosulfate is a drug without appreciable side effects, the council said it would do no harm to continue treatment. Volunteer physicians were reporting permanent recovery in many cases from the treatment. But local doctors were by then opposing it, claiming that any positive results were due to psychosomatic responses. Patients, they said and say now, kept coming back for booster shots that really were doing no good.

"I feel that in the initial stages there was no doubt cyanide was present," says health services director Nagoo. "The toxin that was fixed to the tissues could well have been cyanide. But a year later it is difficult to believe cyanide is present and could be detoxified."

The issue has taken on fierce political and social overtones in Bhopal, causing riots, beatings, and jailing of both morcha demonstrators and volunteer physicians. At one point last summer, police under orders from Madhya Pradesh authorities, broke into thiosulfate dispensaries run by volunteer physicians, arrested them, and confiscated the thiosulfate supplies.

"The cyanide issue is important not merely for its biomedical/toxicological aspects," declares morcha leader Sadgopal, a biochemist who received a Ph.D. in 1968 from California Institute of Technology under James Bonner. "The real importance lies in the legal ramifications. To us it is important because a serious attempt would be made by Carbide lawyers to establish that a large portion of the lung damage can be explained by such things as endemic tuberculosis. It is at this point that the issue of cyanide toxicity would become crucial because if you can establish that so many thousands of people received clinical benefit from sodium thiosulfate injections and you have a clinical record, then you have established that they were suffering from cyanide or cyanidelike toxicity. If sodium thiosulfate gives relief, it is a specific antidote and its effect is shown by a specific chemical urine test for thiocyanate. High levels of it in urine would measure the amount of exposure."

What Sadgopal did manage to do, with the legal help of a Bombay activist lawyer, Indira Jaisingh, was to win an order by the chief justice of the Indian Supreme Court. The chief justice instructed the Madhya Pradesh government to allow the distribution of thiosulfate to volunteer groups, like the People's Medical Center, to continue their treatment. Sadgopal says his case was strengthened by Heeresh Chandra, chief pathologist at Gandhi Medical College in Bhopal. Chandra had been one of the first to detect symptoms of cyanide poisoning and to this day continues to insist that cyanide is still being generated in patients and that thiosulfate therapy is useful. What helped, too, were the March recommendations in favor of thiosulfate by Ramalingaswami's ICMR, which Madhya Pradesh physicians refused to act upon. In a development last month, Sadgopal and Jaisingh also convinced the chief justice to appoint Sadgopal and forensic scientist Chandra to a seven-member committee with direct oversight over the entire clinical program in Bhopal.

The cyanide issue, scientifically speaking, appears to have two aspects. One is direct exposure, which could have occurred during the first hours in the areas closest to the plant. The technical book on this one is closed, although the mystery of why exposure was so vehemently denied by officialdom isn't. The second aspect is indirect exposure owing to unusual generation of toxic amounts of hydrogen cyanide in the body after exposure to MIC.

Worker and colony elder at site of mosque construction

"The way the ICMR scientists have explained the mechanism of cyanide generation makes some sense," says biochemist Sadgopal. "That is the concept of the body's cyanogen pool generating cyanidelike radicals continuously in the bloodstream. When released, they could hook onto the hemoglobin, or to some other enzyme, or to cytochrome oxidase (a key respiratory enzyme). They could either block the respiratory system at the cellular level or modulate the behavior of the hemoglobin in releasing or carrying oxygen.

"Now, the sources that feed into the hypothetical cyanogen pool could be many. One possibility could be MIC linked to a peptide or amino acid, which is gradually hydrolyzed by enzyme action. Then MIC could be converted into thioisocyanate by the transfer of sulfur from thiosulfate. Thioisocyanate existing in equilibrium with thiocyanate is one possibility."

The scheme, though general, does make some hypothetical biochemical sense. MIC binds to hemoglobin in a carbamylation reaction. That binding was a common clinical observation at Bhopal. (The isocyanate-hemoglobin reaction is used to some advantage clinically, too. It is a well-known treatment for sickle cell anemia, because the reaction converts the sickled hemoglobin to a more normal shape.)

A paper just submitted to the *Journal of Chemical Education* by organic chemist Harold Teague of Pembroke State University theorizes a series of reactions by which the MIC-hemoglobin combination could result in the generation of hydrogen cyanide. The reactions involve adenosine triphosphate and a series of electron shifts, resulting in the splitting off of hydrogen cyanide, which would then itself bind to hemoglobin. The success of thiosulfate therapy would then make some sense.

So scientifically, the cyanide issue is intriguing; politically it raises adrenaline levels; and legally it waits a final verdict as to its importance. Right now, it is no consideration in the current legal battle between Carbide and the government of India.

Chemical safety reform in Madhya Pradesh

If words alone are the criterion, Madhya Pradesh appears to be well along the way to cleaning up its industrial safety practices. In the aftermath of Bhopal, says Madhya Pradesh Labor Secretary S. C. Gupta, the first thing his department did was assemble a team of experts to undertake a quick survey of industries that handle chemicals in the state. The team surveyed 61 chemical units, found some deficiencies, and then suggested remedial measures.

"Another action was to give an assignment to Engineers of India Ltd., a design firm, to do safety audits of 11 industries engaged in the manufacture or use of chemicals," he says. "They inspected those units and gave interim reports and pinpointed the deficiencies that were detrimental to health and safety. We wanted to know whether they were detrimental to the health and safety of the workers and whether there could be dangers posed to localities.

"In another activity, the state has established a committee of senior secretaries to examine the question of setting down norms and procedures for ensuring the protection of villages situated in areas affected by the construction of pollution-prone industries. They have a large charter, covering steps for the approval of their operations on environmental grounds, criteria for site selection of major industrial complexes, and procedures for the regular inspection and certification of such facilities. The committee is also examining which parts of existing laws and regulations need to be modified or amended.

Gupta put together another team to examine the central government's Factories Act rules and regulations that directly relate to industrial health and safety. "We found certain lacunae," he reports. "If our inspectors were to find a certain deficiency in a unit, they had no power to suspend operations. There was also no penalty for failure to carry out the recommendations. So we are suggesting that inspectors be given the power to revoke or suspend until deficiencies are rectified. The current penalties are no deterrent. They give three months to carry out improvements, plus a fine of only 2000 rupees."

The Factories Act does not obligate company management to keep communities informed of dangers, nor does it require preventive measures that could be taken. "Many of us did not know the UCIL factory could pose such a danger," Gupta says. "[Management] never mentioned anywhere whether any raw material was toxic. [It] had no obligation to tell us about any change in the process."

In New Delhi itself, reform of the Factories Act is under debate. The urge for reform certainly seems to exist in India, especially in the chemically developed areas around Bombay. The press is quick now to report leaks all over India. Each state has appointed independent inspection teams, trained in chemical engineering, to survey danger spots.

Crucial court decision approaches in suits by Bhopal victims

It has been 10 months since most of the 119 lawsuits filed in the U.S. on behalf of individual Bhopal victims against Union Carbide were consolidated in the U.S. District Court for the Southern District in Manhattan. Nearly eight months have passed since the government of India sued Carbide in the same court, and more than four months have elapsed since Carbide moved to have the actions dismissed on the grounds that the U.S. was not the proper forum for the case. Now, with much of the preliminary legal work completed, the stage is set for a decision crucial to all parties.

On Jan. 3, 1986, attorneys for both sides will present oral arguments on the dismissal motion to federal judge John F. Keenan, who is presiding over the proceedings, in the Manhattan court. Judge Keenan's ruling on the dismissal motion could come on the same day or after a period of consideration. It is also possible, though not expected, that the judge could request additional information before issuing his ruling.

Whatever the timetable, the future course of the case in the U.S., and, probably, the tack of future settlement negotiations, hinges on the ruling. If the case remains in the U.S., Carbide could ultimately face American-scale damages, which are far higher than those generally awarded for personal injury in Indian courts. Therefore, legal experts believe, the company's bargaining position would be weakened and India could demand more money to settle its suit. On the other hand, a ruling for dismissal would strengthen Carbide's negotiation stance. Negotiations have been stalled, apparently awaiting the court ruling, since a reported $300 million offer by Carbide was turned down by the Indians last summer.

Key to the ruling is the judge's interpretation of the briefs and oral arguments in the light of forum non conveniens, a legal doctrine that can be used to determine whether the forum chosen by the plaintiffs is a suitable tribunal. Carbide's contention, under the doctrine, is that the actions should be moved to India because the disaster occurred there, the plaintiffs are all Indians living there, "essential" witnesses and evidence are located there, and many suits have been filed there. Underlying the company's point of view is its insistence that whatever liability may be involved should not include Union Carbide Corp., the parent firm, but only Union Carbide India Ltd. (UCIL), the company which operated the Bhopal plant and which is owned 50.9% by the parent firm.

Attorneys for the plaintiffs, on the other hand, have argued that the parent firm is responsible for the acts of its subsidiary. Acceptance of that premise, they contend, means many important witnesses and much crucial evidence on the design of the plant and control of its operation are located in the U.S. And that, they say, makes the U.S. court the proper one.

Because Carbide holds that the parent firm is not liable in the case, it wanted to shield itself from discovery inquiries until after the forum issue was decided. The plaintiffs, conversely, argued that since the liability of the parent firm was critical to their contention that the case should stay in the U.S., they needed a discovery period before final arguments on the dismissal motion were heard. Judge Keenan, looking for a middle road, allowed a limited discovery, under which only interrogatories related directly to the forum issue were permitted.

Most of the information learned in discovery will not be made public until the briefs are filed, but Bud G. Holman, Carbide's chief attorney, says his side's inquiries uncovered "an enormous amount of information favorable to Union Carbide." He asserts, for instance, that involvement of Indian engineers in the design and construction of the Bhopal plant was greater than previously thought. Michael V. Ciresi of Robins, Zelle, Larson & Kaplan, the law firm representing India, declines to comment on what his side learned from discovery, citing a confidentiality order by the judge.

At the same time that the legal watershed grows nearer, Carbide seems to be increasingly emphasizing the theory that sabotage, rather than an inadvertent action, was responsible for the accident. Lawyer Holman admits he has no direct evidence of sabotage, but says that getting the water into the tank "was so improbably inadvertent that our conclusion is that it was deliberate." He adds that the plant library contained information that would have been useful to a saboteur and that it was open to most employees.

Ciresi scorns the sabotage theory as "the product of a runaway imagination. They have no facts to support it," he says, "and they know it."

If Judge Keenan rules in favor of Carbide on the forum issue, the plaintiffs will have the right to appeal. If the case is kept in the U.S., Ciresi says, the plaintiffs' attorneys will try to move it to trial quickly, with discovery cut off by the end of June, the summer for pretrial motions, and an opening trial date of Sept. 1, 1986.

David Webber, New York

But although the Indian technical community is paying heed to the country's own deficiencies, it is also insisting that the West refrain from regarding the country as a technological backwater.

"Chemical accidents before and after Bhopal in the developed countries show that chemical technology is not necessarily managed more intelligently there," says chemist G. Thyagarajan, a Council of Scientific & Industrial Research laboratory director and head of the government's technical Bhopal investigation team. "Runaway reactions do not make a distinction between developing and developed countries. Did Flixborough [the 1974 chemical disaster in England] happen in a developing country? Did the Seveso poisonous gas leak occur in a poor developing country? Why did a toxic gas leak occur last August in a Union Carbide plant whose safety was said to have been beefed up by the spending of $5 million?"

There is no lack of scientific and technological talent and imagination in India. Indian scientists point

New house in J. P. Nagar (left) Thyagarajan (above): no distinction

to the giant government-owned Indian Petrochemicals Ltd. (IPCL) complex at Baroda that licenses western technology, and the privately owned National Organic Chemicals India Ltd. (NOCIL) pesticide plant at rural Chiplun, south of Bombay. Managers in those plants all make the point of saying UCIL's operation at Bhopal was not representative of anything near what indigenous Indians can do. Discussions with Indian scientists, engineers, industrial management figures, bureaucrats, journalists, and activists all lead to that one point. The feeling is that Carbide bungled Bhopal badly. It was trying to push a product, Sevin, whose market potential in India was dwindling. It knew it, was hoping to sell off its Bhopal plant, and had virtually given up on it. The stage seemed set for disaster.

As far as the long-term effects of Bhopal on India's consciousness, even activists are pessimistic. Says Vijay Varma, a physicist at Delhi University, who is active in the reform of science education in Madhya Pradesh: "Bhopal happens and the general feeling is that it is an act of Providence, not likely to happen again. I think the West will learn from Bhopal more than we will here. As long as the government is doing the enforcing, the process will be too corrupted. The only meaningful solution is for independent experts to take over enforcement."

Even activist Sadgopal has second thoughts. "It is amazing that we have not been able to explain the sociopolitical issues involved in the Bhopal tragedy even to the people of Bhopal—the role of the multinational, the kind of development model we have chosen, in which the use of such pesticides and highly toxic materials is allowed, or the character of science and technology as practiced in the country, or the suppression of vital medical and scientific information by Carbide assisted by our government."

Gokhale is an especially dramatic figure, in some ways a character out of a Greek tragedy. He wants his fellow Indians to know that his company has made every effort to demonstrate that the Carbide family cares very deeply about the plight of Bhopal's gas-affected survivors. Legally, he asserts blamelessness. He defends the management of the plant. Corporately, he stands together with the U.S. parent company. The trouble is that the parent isn't standing together with him. The managerial blame has been placed on UCIL by Carbide in Danbury. The parent firm believes that because mistakes were made in Bhopal, and because UCIL had full managerial responsibility, then the case should be shifted to India. "Fifty years of contributions to Indian society seem to have disappeared after this tragedy," Gokhale laments.

So although Carbide and UCIL both believe that the place of trial should be India, no one really wants a trial. All parties, except for various activist groups who want to punish Carbide, would prefer an out-of-court settlement. But that has complications, too, over the worth of an Indian life. Indian government sources close to negotiations say India would accept something less than $1 billion distributed by a formula that would ensure upfront costs and support to those suffering long-term pathologies. In addition, criminal charges against both companies would be dropped, those sources say.

There is a continuing vastness to the subject of Bhopal, one year after the calamity that so rocked the conscience of the chemical industry. The lesson then, as now, is that another Bhopal cannot be allowed to happen. Safety audits are the order of the day, in India and in the rest of the world. Workshops and symposia on industrial and community safety are densely scheduled. The chemical world has learned, because industrial disasters—so enormously wasteful of money, human energy, and long-built reputations—do teach. □

Reprints of this C&EN special report will be available at $5.00 per copy. For 10 or more copies, $3.00 per copy. Send requests to: Distribution, Room 210, American Chemical Society, 1155—16th St., N.W., Washington, D.C. 20036. On orders of $20 or less, please send check or money order with request.